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PRELIMINARY DESIGN

FOR

DRINKING WATER TREATMENT PROCESS SYSTEMS

by

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16. ABSTRACT

The purpose of this study was to develop a computer program to aid the design engineer in evaluating the performance and cost for any proposed drinking water treatment system consisting of the individual unit process. The 25 unit process models currently in the program include both conventional and advanced contaminant removal processes and various sludge handling techniques. Technology used in sizing processes, estimating performance, and estimating treatment cost is the best currently available for preliminary design. To use the program, the designer unit must prepare a flow diagram, input the raw water quality, and provide cost and design decision parameters. By varying this information, the user can perform sensitivity analysis on his proposed design or compare the performance and cost of alternative designs in order to obtain the best possible treatment at a minimum cost.

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PRELIMINARY DESIGN FOR DRINKING WATER TREATMENT PROCESS SYSTEMS

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A computer model has been developed for use in estimating the performance and associated costs of proposed and existing water supply systems. Design procedures and cost-estimating relationships for 25 unit processes that can be used for drinking water treatment are contained within the model. The unit processes were selected on the basis of their applicability to the removal of contaminants included in the National Interim Primary Drinking Water Regulations or to the treatment and disposal of sludges and brines produced by these treatment processes. Two versions of the computer model have been developed in order to provide more flexibility in its use. The first version is an interactive computer program called WATER MAID that is written in the BASIC computer language for use on the IBM PC microcomputer. The second version is a computer program called DWCAD that is written in the FORTRAN computer language for use on a minicomputer or larger size computer system. Both programs calculate the same results, but rely on different input and output procedures. A user's guide exists for both programs.

Estimating the performance efficiency and cost of water supply systems is of considerable interest to Federal, State, and local agencies, as well as to utilities, consulting engineers, and planners. The computer model can be used to calculate the expected contaminant removal performance and associated construction and operation/maintenance costs of drinking water treatment systems consisting of various unit treatment processes arranged in multiple configurations. The technology used in sizing unit processes, estimating removal efficiencies, and determining treatment cost is the best that is known to be currently available for preliminary design. Since the technology for each process is contained in individual subroutines of the computer model, improving and updating the technolgy when more information becomes available is easily accomplished. The structure of both programs allows for the inclusion of additional unit process models if desired. The following lists the unit processes currently contained in the computer model:

1. Raw water pumping
2. Presedimentation
3. Rapid mixing of chemicals
4. Flocculation
5. Sedimentation
6. Filtration
7. Granular carbon adsorption
8. Lime softening
9. Lime sludge recalcination
10. Ion exchange
11. Reverse osmosis
12. Basin air stripping
13. Tower air stripping
14. Sludge gravity thickening
15. Sludge vacuum filtration
16. Sludge centrifugation
17. Sludge filter pressing
18. Sludge dewatering lagoons
19. Sludge drying beds
20. Sludge land disposal
21. Disinfection with chlorine
22. Clearwell storage
23. Finished water pumping
24. Stream mixer
25. Stream splitter

The user of either program must provide the influent concentrations or values for a list of 55 contaminants and other parameters that characterize the quality of the raw water stream entering the treatment system and a set of unit proceses to be used, which are arranged in a specific flow diagram. The model then computes one or more effluent stream vectors and cost estimates for each unit process based on design input decisions supplied by the user. The following lists the water parameters and contaminants included in the stream vector (all concentrations are in mg/L unless otherwise specified):

1. Design flow rate, mgd
2. Water temperature, °C
3. pH
4. Turbidity, ntu
5. Color, pcu
6. Coliform organisms, #/100 mL
7. Total dissolved solids
8. Total suspended solids
9. Volatile suspended solids
10. Carbonate alkalinity
11. Non-carbonate alkalinity
12. Calcium ion
13. Magnesium ion
14. Sodium ion
15. Copper
16. Ferrous ion
17. Ferric ion
18. Bivalent manganese
19. Quadravalent manganese
20. Chloride
21. Sulfate ion
22. Nitrate ion
23. Total organic carbon
24. Nonpurgeable organic carbon
25. Pentavalent arsenic
26. Trivalent arsenic
27. Barium
28. Cadmium
29. Hexavalent chromium
30. Trivalent chromium
31. Lead
32. Mercury
33. Organic mercury
34. Quadravelent selenium
35. Hexavalent selenium
36. Silver
37. Fluoride
38. Endrin
39. Lindane
40. Toxaphene
41. 2,4,D
42. Silvex
43. Methoxychlor
44. Gross alpha particle, pCi/L
45. Radium-226, pCi/L
46. Radium-228, pCi/L
47. THM formation percursors
48. $CHCl_3$ (THM), ug/L
49. $CHBrCl_2$ (THM), ug/L
50. $CHBr_2Cl$ (THM), ug/L
51. $CHBr_3$ (THM), ug/L
52. Aluminum hydroxide
53. Ferric hydroxide
54. Calcium carbonate
55. Magnesium hydroxide

The cost related information that is estimated for each unit process includes the following:

1. Construction cost, $
2. Capital investment cost, $
3. Amortization cost, $/yr
4. Operating cost, $/yr
5. Total treatment cost, $/yr
6. Unit debt cost, ¢/1000 gal
7. Unit operating cost, ¢/1000 gal
8. Total unit treatment cost, ¢/1000 gal
9. Operating labor, hrs/yr
10. Building energy, kwhr/yr
11. Operating energy, kwhr/yr
12. Materials and supplies, $/yr
13. Diesel fuel, gal/yr
14. Natural gas, cu ft/yr
15. Chemicals, $/yr

The WATER MAID program, with MAID being an acronym for microcomputer assisted interactive design, allows design decision parameters and other input data to be entered directly from the computer keyboard in response to screen prompts. This procedure is quite helpful to those individuals who are not completely at ease with working on computers or have somewhat limited experience in process design. Suggested input

values are supplied to the user if no better information is available. The user thereby has the capability of "feeling" his way through the computer model. The general philosophy used in developing WATER MAID was to allow the user to input every possible design decision, to display the results of each design computation as it is made, and to inform the user when design decisions are made by the program. The user is given the opportunity to change the raw water stream vector or to change any of the cost variables or chemical prices when a new case is initiated. Recycling capability is provided if needed. The raw water stream vector and process flow diagram specified by the user are stored and can be used in the next case if desired. Stream vectors for influent and effluent streams and a cost report are displayed after each unit process computation. An overall cost and design parameter summary report for the complete treatment system is displayed after each case. Design flow is used to compute construction cost and building energy requirements, and operating flow is used to calculate operation/maintenance costs. The user may also delete a unit process from the flow diagram or replace any unit process with another after each process computation. This allows the user to consider alternative processes without rerunning the program. The disadvantages to using WATER MAID are the numerous pieces of input data that must be entered from keyboard, the inability to easily rerun a case if an input mistake is made or if only a few input data changes are necessary, the length of run time necessary for computation on a microcomputer, and the slow printing of the output calculations.

The DWCAD program, with DWCAD being an acronym for drinking water computer assisted design, allows all program input to be entered or updated quickly from previously created data files stored in the computer. This greatly simplifies the running of additional cases to correct errors or perform multiple case calculations such as required for sensitivity analysis. The FORTRAN version also runs and prints very efficiently. The only disadvantage would be the need and expense for access to a large computer system having a FORTRAN compiler. DWCAD users would need some knowledge of computer programming and operations. Output information from DWCAD is similar to that of WATER MAID except that it is presented in a different format.

The computer model was developed to provide an efficient preliminary process design tool for the water supply field. The primary purpose is to evaluate any proposed system of drinking water treatment processes with respect to treatment effectiveness and cost with a minimum of engineering effort. Technology used in the development of individual process models is consistent with the state of the art. However, in many cases, the need for additional research is clear. Updating the technology when improved performance, cost, and design information becomes available can be done by the user. Cost estimating data used in the model came from technical literature, equipment manufacturer information, U.S. EPA research projects, etc. Treatment system capacity limits for the cost data has been set at 1 to 200 mgd. The computer model approach provides a more flexible preliminary cost estimating tool than that provided by graphical or tabular cost data. Cost estimating procedures or data bases are often presented at a number of specific design parameter levels, such as pumping heads or hauling distances for sludge, thus limiting their general applicability. When a cost estimating algorithm is known, it can be used in the model in place of mathematical representations of tabular data,

thus providing more accurate cost estimates. Some of the design procedures used in the computer programs are limited by the availability of cost information.

This computer model represents a mathematical modeling effort that is a significant improvement on the hand calculation method of process design that is still commonly used today. The principal deterrents to better process design are usually the manual effort required in computing the expected performance and cost of alternative designs and the labor required to accumulate and correlate the large amount of experimental process design performance data that is often available. The computer model can minimize the computational work required for examining alternative designs, and assuming that the model has been correctly developed, it will reflect the best experimental and scientific information obtainable. This model provides the process designer with a tool for quantitatively selecting the most cost-effective system of unit processes to achieve any drinking water treatment goal. The use of computer design techniques is a significant aid in achieving better treatment at a minimum cost.

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